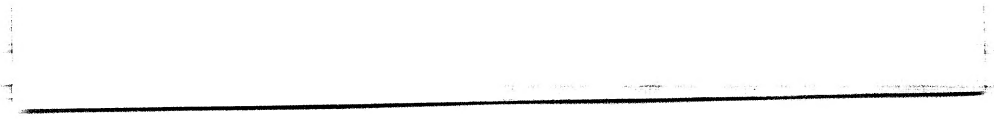

AN INTRODUCTION TO CYBERNETICS

By the same author

DESIGN FOR A BRAIN

AN INTRODUCTION TO CYBERNETICS

by

W. ROSS ASHBY

M.A., M.D.(Cantab.), D.P.M.

Director of Research

Barnwood House, Gloucester

NEW YORK

JOHN WILEY & SONS INC.

440 FOURTH AVENUE

1956

First published 1956

PRINTED IN GREAT BRITAIN BY
WILLIAM CLOWES AND SONS, LIMITED, LONDON AND BECCLES

PREFACE

Many workers in the biological sciences—physiologists, psychologists, sociologists—are interested in cybernetics and would like to apply its methods and techniques to their own speciality. Many have, however, been prevented from taking up the subject by an impression that its use must be preceded by a long study of electronics and advanced pure mathematics; for they have formed the impression that cybernetics and these subjects are inseparable.

The author is convinced, however, that this impression is false. The basic ideas of cybernetics can be treated without reference to electronics, and they are fundamentally simple; so although advanced techniques may be necessary for advanced applications, a great deal can be done, especially in the biological sciences, by the use of quite simple techniques, provided they are used with a clear and deep understanding of the principles involved. It is the author's belief that if the subject is founded in the common-place and well understood, and is then built up carefully, step by step, there is no reason why the worker with only elementary mathematical knowledge should not achieve a complete understanding of its basic principles. With such an understanding he will then be able to see exactly what further techniques he will have to learn if he is to proceed further; and, what is particularly useful, he will be able to see what techniques he can safely ignore as being irrelevant to his purpose.

The book is intended to provide such an introduction. It starts from common-place and well-understood concepts, and proceeds, step by step, to show how these concepts can be made exact, and how they can be developed until they lead into such subjects as feedback, stability, regulation, ultrastability, information, coding, noise, and other cybernetic topics. Throughout the book no knowledge of mathematics is required beyond elementary algebra; in particular, the arguments nowhere depend on the calculus (the few references to it can be ignored without harm, for they are intended only to show how the calculus joins on to the subjects discussed, if it should be used). The illustrations and examples are mostly taken from the biological, rather than the physical, sciences. Its overlap with *Design for a Brain* is small, so that the two books are almost independent. They are, however, intimately related, and are best treated as complementary; each will help to illuminate the other.

It is divided into three parts.

Part I deals with the principles of Mechanism, treating such matters as its representation by a transformation, what is meant by "stability", what is meant by "feedback", the various forms of independence that can exist within a mechanism, and how mechanisms can be coupled. It introduces the principles that must be followed when the system is so large and complex (e.g. brain or society) that it can be treated only statistically. It introduces also the case when the system is such that not all of it is accessible to direct observation—the so-called Black Box theory.

Part II uses the methods developed in Part I to study what is meant by "information", and how it is coded when it passes through a mechanism. It applies these methods to various problems in biology and tries to show something of the wealth of possible applications. It leads into Shannon's theory; so after reading this Part the reader will be able to proceed without difficulty to the study of Shannon's own work.

Part III deals with mechanism and information as they are used in biological systems for regulation and control, both in the inborn systems studied in physiology and in the acquired systems studied in psychology. It shows how hierarchies of such regulators and controllers can be built, and how an amplification of regulation is thereby made possible. It gives a new and altogether simpler account of the principle of ultrastability. It lays the foundation for a general theory of complex regulating systems, developing further the ideas of *Design for a Brain*. Thus, on the one hand it provides an explanation of the outstanding powers of regulation possessed by the brain, and on the other hand it provides the principles by which a designer may build machines of like power.

Though the book is intended to be an easy introduction, it is not intended to be merely a chat about cybernetics—it is written for those who want to work themselves into it, for those who want to achieve an actual working mastery of the subject. It therefore contains abundant easy exercises, carefully graded, with hints and explanatory answers, so that the reader, as he progresses, can test his grasp of what he has read, and can exercise his new intellectual muscles. A few exercises that need a special technique have been marked thus: *Ex. Their omission will not affect the reader's progress.

For convenience of reference, the matter has been divided into sections; all references are to the section, and as these numbers are shown at the top of every page, finding a section is as simple and direct as finding a page. The section is shown thus: S.9/14—indicating the fourteenth section in Chapter 9. Figures, Tables, and

Exercises have been numbered within their own sections; thus Fig. 9/14/2 is the second figure in S.9/14. A simple reference, e.g. Ex. 4, is used for reference within the same section. Whenever a word is formally defined it is printed in **bold-faced** type.

I would like to express my indebtedness to Michael B. Sporn, who checked all the Answers. I would also like to take this opportunity to express my deep gratitude to the Governors of Barnwood House and to Dr. G. W. T. H. Fleming for the generous support that made these researches possible. Though the book covers many topics, these are but means; the end has been throughout to make clear what principles must be followed when one attempts to restore normal function to a sick organism that is, as a human patient, of fearful complexity. It is my faith that the new understanding may lead to new and effective treatments, for the need is great.

Barnwood House
Gloucester

W. ROSS ASHBY

CONTENTS